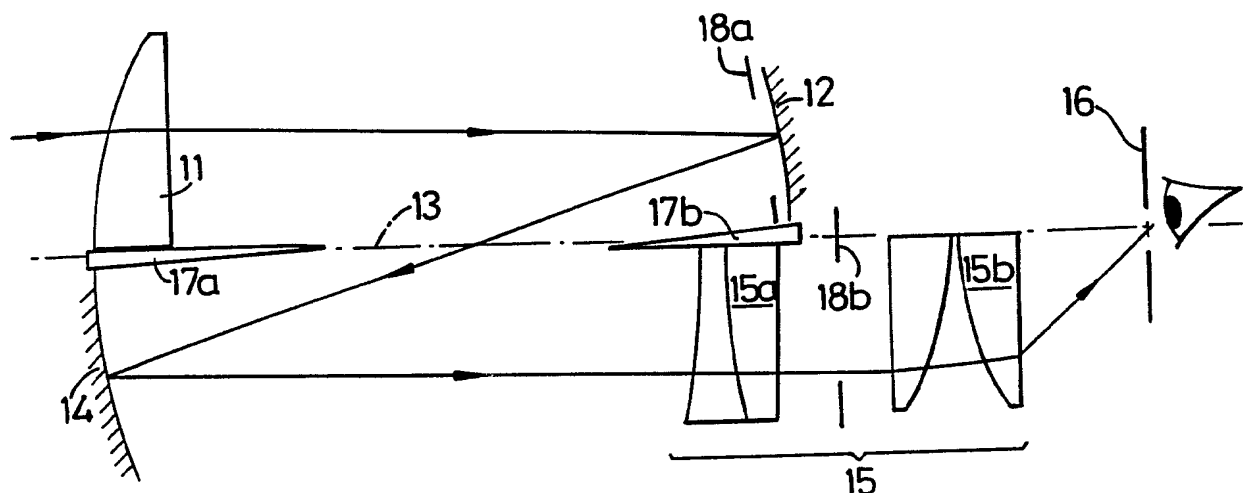


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(54) Title: OPTICAL SYSTEMS, TELESCOPES AND BINOCULARS**(57) Abstract**

An optical system for a telescope or a pair of binoculars has an optical path folded by erecting mirrors (12 and 14) and is arranged to give an inherent aperture and field greater in one direction than another. By using a low power eye piece lens means it is possible to arrange for the user's eye or eyes to be further behind the said means so he can wear his normal spectacles to correct for eye defects. When a pair of systems is used in a pair of binoculars, it is possible for the exit pupils to be in the form of horizontal slots so the systems do not have to have adjustable spacing to allow for the user's eye separation.

+ DESIGNATIONS OF "SU"

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-1-

OPTICAL SYSTEMS, TELESCOPES AND BINOCULARS

FIELD OF THE INVENTION

The present invention relates to optical systems for
5 viewing devices such as binoculars and telescopes and
relates to binoculars and telescopes.

BACKGROUND OF THE INVENTION

Optical systems used in binoculars have optical paths
folded by means of reflective prisms and are arranged to
10 give erect images. The substitution of prisms by mirrors
has been analysed in a paper "Camera viewfinder using
tilted concave mirror erecting elements" by Donald DeJager
in the SPIE Vol 237 at page 292 of 1980 but the
arrangement was found unsatisfactory due to excessive
15 amounts of astigmatism, variation of focus across the
field, distortion and coma. Arrangements using erecting
mirrors are also described in US Patents 4598981, 4804258,
4758077, 4221459 and 3897133. The first two do not
incorporate any lenses and solely use mirrors which do not
20 have an erecting function. The last three have circular
fields and apertures with the last one having an annular
aperture and it is known that annular apertures give poor
visual images. The present invention in one of its
aspects aims at providing an approach whereby an optical
25 system can use mirrors whilst giving acceptable
performance with compact shape.

SUMMARY OF THE PRESENT INVENTION

One aspect of the present invention provides an
optical system for telescopes and binoculars having an
30 optical path folded by erecting mirrors and comprising at
least one lens characterised in that the system has an
inherent aperture and field greater in a direction
transverse to a direction in which the path is folded.

Normally the optical systems would have an objective
35 lens unit and an eyepiece lens means with an additional
aspect of the present invention providing an optical

-2-

system for telescopes and binoculars comprising an objective lens unit and an eyepiece lens unit with an optical path there between folded by erecting mirrors characterised in that the system has an aperture and field
5 greater in a direction transverse to a direction in which the path is folded.

In use the greater field and aperture will be horizontal and the smaller field vertical. This will be acceptable for most uses such as scanning the horizon and
10 permits a very advantageous binocular design to be designed with the optical paths folded tightly on themselves possibly in the shape of a Z or with the optical path folded so as to cross itself.

In the said optical system the smaller field and
15 aperture may be offset so that the optical system may otherwise be centred about a single axis as is the case in most optical systems where all the surfaces have their centres of curvature lying on a single axis.

The invention is not limited to the mirrors,
20 objective lens unit and eyepiece lens means having spherical surfaces but these can be aspheric such as parabolic or toroidal. In this event such surfaces do not have a single point centre of curvature and when used with off-axis apertures will tend to have centres of curvature
25 blurred over a volume in space centred about two locations and with the volume increasing with increased aperture. The Gauss centre of curvature or the centre of curvature of the best-fit sphere can be taken as a representative value and will herein be termed the centre of curvature.
30 This centre of curvature will also be used to define a mean radius of curvature.

It is convenient to define the positions of some of the centres of curvature in relation to a viewing axis which is the line joining the centre of the viewed object
35 to the centre of the user's eye through the system when the system is being used.

-3-

It has been said that the folded path can be in the nature of a Z. The angles contained in the Z are preferably no greater than 30° and this can be achieved by offsetting the used areas of the objective lens unit, mirrors and eyepiece lens means from the viewing axis possibly assisted by having the centres of curvature of the mirrors at distances not more than 20% but preferably less than 10% of their radii of curvature from the viewing axis and the centres of curvature of the objective lens unit and eyepiece lens means displaced by up to about twice the greater of said distances. The Z can be slightly skew that is with the bottom bar of the Z not parallel with the top bar so that the spacing of the objective lens units in a pair of binoculars can differ from the spacing of the eyepiece means. If the folded path is not Z shape, the optical path could still be as tightly folded and skewed.

In its basic form if the system were generally horizontal, the field seen by the objective lens unit would be below the horizon and the final image viewed by the user's eye after magnification would appear to be even further below the horizon by the amount of the magnification. This in some instances may be an advantage but at least the displacement of the image can be corrected by further optical elements and/or the discrepancy of the direction of the system and the horizon can be corrected by design of a housing.

The mirrors need not be simple mirrors but could for example be more complex. For example, at least one mirror could be a so-called Mangin mirror comprising a lens with a reflective rear surface which would of course alter the effective centre of curvature.

The optical systems according to the present invention lend themselves to combination in pairs to form binoculars with the systems generally parallel and with

-4-

the smaller field and aperture in each case vertical that is at right angles to the plane through the two systems forming a pair of binoculars.

Another aspect of the present invention concerns a
5 pair of binoculars having exit pupils in the form of horizontal slots.

If these slots are long enough, say up to twenty but typically eight or nine millimetres, they will form linear eye rings so that there will generally be no need to
10 adjust the separation of the two systems as in conventional binoculars to match the separation of the user's eyes.

The invention will now be described by way of example with reference to the accompanying drawings.

15 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic axial section of an optical system according to the present invention,

Figure 1a illustrates the shapes of mirrors, objective lens unit and eyepiece lens means used in Figure
20 1,

Figure 2 illustrates the field of view given by the present invention,

Figure 3 illustrates a linear exit pupil that can be provided according to the present invention,

25 Figure 4 illustrates a modification to the system shown in Figure 1,

Figure 4a shows the shape of mirrors, objective lens unit and eyepiece lens means that can be used in Figure 4,

Figure 5 illustrates a different arrangement of an
30 optical system,

Figure 6 is a perspective view of a pair of systems according to Figure 1 or Figure 4 arranged as a pair of binoculars,

Figure 7 is a side view of a housing for a pair of
35 binoculars,

Figure 8 is a schematic axial section of another optical system,

Figure 9 illustrates a further optical system,

Figure 10 illustrates a telescopic housing for the system of Figure 8,

Figure 11 is a view similar to Figure 1 for a low power optical system using a Mangin mirror as the first inverting mirror to identify surfaces referred to in tables given below.

Figure 12 is a view similar to Figure 11 but having a high power magnification system.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

Figure 1 illustrates the basic concept of an optical system according to the present invention. Light from an object, which may be infinitely distant so that the light is in the form of substantially parallel bundles of light rays, enters the optical system through an objective lens unit 11 which may be a single lens and after a distance from that unit impinges on a first erecting mirror 12. The unit has a focal length such that it forms an image reasonably close to the mirror so as to minimise pupil aberrations due to the mirror. The mirror has an effective radius of curvature half to twice the said distance. The path of the light is folded into a Z-shape with the included angles up to 30°. The light after reflection by the mirror 12 is directed onto a similar second erecting mirror 14 which redirects the light to be largely parallel to the original direction and forms an image to be viewed by an eyepiece lens means 15. This means directs the light substantially collimated through an exit pupil 16. The image to be viewed by the eyepiece lens means will be in many cases straddled by components 15a and 15b of the eyepiece lens means, which conveniently is below the mirror 12, in the manner of a Huygens-type eyepiece. One or each of the mirrors can be a simple concave element or a planar or even convex mirror combined

-6-

with lenses in the manner of a Mangin mirror which largely performs as a concave mirror. To ensure that only the desired light reaches the eye, baffles 17a and 17b of opaque material can be provided, as can field stops 18a and 18b, in any advantageous positions. In this embodiment the centres of curvature of the mirrors' and the unit and means' surfaces can all lie on the same axis 13. A view on the objective lens unit and the back face of the mirror 14 or on the back face of mirror 12 and the eyepiece lens means would be as shown in Figure 1a with the various items being semicircular or truncated as shown by chain-dot lines 11a and 14a. In Figure 2, the field of view of the system is as shown in full lines 30 (for comparison the circular field obtained with conventional binoculars is shown in broken lines 31). It will be seen that the field with the present system is reduced from a wider overall field so as to leave a wider field of view in one direction (usually horizontal) and a narrower field of view in a direction transverse to said one direction. Chain dot line 30a shows the field when the unit mirrors and means are as shown with reference to lines 11a and 14a. The wider field of view is in a direction transverse to a direction in which the optical path is folded. There are two such directions of fold in some arrangements, a direction which is generally in the vertical plane containing the viewing axis and another direction slightly skew to that direction to allow for different spacings of the objective lens units and the user's eyes but such directions are substantially the same. The field of view with the present system is not centred with the wide overall field nor with the conventional field but this may not be significant.

Figure 3 shows the exit pupil 32 available with the present invention compared with the exit pupil 33 of conventional optical systems (chain-dot line 32a corresponds to lines 11a and 14a). This exit pupil is in

-7-

the form of a slot up to 20mm long but typically 8 to 9mm. This yields advantages when a pair of optical systems are combined into binoculars when the exit pupils can be in line and there would be no need to allow for adjustable
5 separation of the optical systems to accommodate different eye spacing of various users. The wide field of view and the wide exit pupil being in the same orientation does not lead to excessive coma since a user's eye will not accept light from the entire pupil but only from part of it. Any
10 coma and the resulting anamorphic distortion due to using a non-central viewing position can be minimised by optical design.

Figure 4 illustrates the effect of making the angle of fold less tight so the optical axes of the objective
15 lens unit 11 and the eyepiece lens means are not in the same horizontal plane but in spaced apart planes. This permits better baffles 17a and 17b and the mirrors, objective lens unit and eyepiece lens means to be more than semicircular as shown in Figure 4a. The centre 12'
20 of curvature of mirror 12 would in this event be displaced by not more than 20% but preferably less than 10% of the radius of curvature from the viewing axis and the centre 14' of curvature of mirror 14 similarly displaced. Thus Figure 4 represents a decentred system wherein the optical
25 system does not have a single axis and Figure 4a shows the appearance of this in the same manner as Figure 1a. The systems as illustrated select from the overall view an object field from the lower part of that overall view (ie the system looks slightly down) so that the inverted image
30 projected in the vicinity of the first mirror is wholly or mainly above the optical axis of the objective lens unit. This enables a vertically compact design which does not require fold angles greater than 30°.

Figure 5 shows a different optical geometry. The
35 objective lens unit 11 is below the viewing axis and the light path crosses itself.

Optical systems according to the present invention
lend themselves to combinations in pairs to form
binoculars with the two systems parallel and with the
larger field horizontal as shown in perspective in
5 Figure 6.

Figure 7 shows a suitable housing 51 for the two
systems of a pair of binoculars. This housing is formed
as a flattish box with an upper member 52 pivoted to a
lower member 53 by a hinge 54 so that the two members can
10 be pushed together when the binoculars are not in use and
then freed by a suitable catch (not shown) so that a
spring (not shown) can push the members ajar for use into
the illustrated condition. The upper member carries the
objective lens units and the mirrors 12 with the lower
15 member carrying the mirrors 14 and the eyepiece lens
means, the mechanical arrangement should be such that the
various components would not interfere with the two
members being pushed together thus for example in Figure 1
the objective lens unit 11, the baffle 17a and the mirror
20 14 could not be as shown but the unit 11 must be further
to the left or right as shown in the drawings. The hinge
54 can be used as a mounting or attachment point for a
carrying strap 55. The upper member has a forward
extension or extensions 56 acting as a lens hood and a
25 rearward extension or extensions 57 acting as a brow rest
or rests to space the binoculars from the wearer's eyes.
Miniature periscopes 58 may be provided above each of the
user's eyes in or near the brow rest or rests to allow the
user to see a direct view of the object as well as the
30 magnified view which is seen below the direct view. The
top of the housing can be sloped at least in part so that
the top surface can be aligned with the distant object or
the apparent object can be moved by means of a prism but
such provision may not be necessary and aiming can be done
35 by the periscopes. (The feel of the binoculars may not
matter.)

It has been said that the field as shown in Figure 2 is centred below the centre seen with conventional binoculars. This can be corrected as shown in Figure 8 by using a pair of plane mirrors 19 and 20 arranged generally as a periscope as shown within the eyepiece lens means so as to allow the component 15b of the eyepiece lens means to be tilted. The spacing between the components 15a and 15b of the eyepiece lens means can be increased to accommodate these mirrors and the longer optical path produced if the mirror 14 projects an image further to the right.

Figure 9 shows a modification of Figure 8 in which the direct view or periscope facility mentioned in relation to Figure 7 is provided within the eyepiece lens means by inserting a compensating lens 21 between lenses 15b and either rotating the mirror 20 or inserting a new mirror 22. The mirror 20 or mirror 22 would direct the optical path up to a permanent mirror 23 so forming a periscope. The component 15b with the lens 21 in place would have negligible optical effect so the direct view would not be magnified but the system would be readily switched to a magnified view by a mechanism (not shown) for inserting the lens 21 and either rotating mirror 20 or inserting mirror 22.

Figure 10 shows an alternative to the housing shown in Figure 7 in which two housing parts 25 and 26 can be extended telescopically from a shorter (as shown) non-use condition to a longer in-use condition.

In relation to Figure 7 mention has been made of a brow rest. The design of the optical system according to the present invention wherein the use of erecting mirrors which tend to introduce negative field curvature offsetting the positive field curvature normally present enables the power of optical surfaces in the eyepiece lens means to be reduced and for the user's eye to be further behind the eyepiece lens means. This enables the user to

-10-

use his own spectacles which will correct for the user's optical faults such as long-sightedness, short-sightedness and astigmatism freeing the optical system according to the present invention from the need to
5 be adjustable to cope with these. The main requirement is then to focus for near and distant objects and this could be done by arranging mirrors 12 and 14, eyepiece lens means and/or objective lens unit, or the mirrors 19 and 20, to be displaceable a small distance (less than 3 or 4
10 millimetres possibly) by a spring loaded action or actions. In binoculars the focusing action can be achieved by having both systems adjustable as one although separate focusing is possible.

The optical systems can be fitted in the housing as
15 illustrated in Figures 1 to 5 or upside down.

The optical performance can be optimised by the complexity and quality of the mirrors, objective lens unit and eyepiece lens means. In general spherical aberration and longitudinal colour will be controlled at the
20 objective lens unit and the mirror 14, lateral colour and astigmatism within the eyepiece lens means, curvature of the field largely by balancing the effects of the mirror reflections and refractions in the unit and the means, and coma by arranging that the light deviates less at larger
25 apertures and more at smaller apertures. The mirrors, unit and means can have more components than shown and may use complex forms such as doublet or triplet lenses.

In each system the limited vertical field is obtained by the shapes of the mirror, objective lens unit, eyepiece
30 lens means and/or the stops. Instead of stops, field lenses could be used.

Figures 11 and 12 are views similar to Figure 1 giving respectively a low and a high power system except that in Figure 11 the mirror 12 is a Mangin mirror with
35 the lens part of the mirror being that part of the eyepiece lens component 15a (which is cut away in Figure

-11-

1) above the viewing axis and which part is silvered at 59 to form the mirror and in Figure 12 the mirror 12 is similarly formed but on an auxiliary lens 60 disposed between the mirror and the eyepiece means. These figures are referenced to give the various surfaces referred to in the accompanying tables given below.

Table 1 4X magnification version

Surface Number	Radius of Curvature (mm)	Axial Separation (mm)	Refractive Index	V-value (constringence)
10				
61	77.691 ^(A)	9.72	1.49176	57.45
62	-573.515	107.10	AIR	
63	248.631	16.00	1.65713	49.55
15				
64	-36.314	3.00	1.71300	53.83
65	-236.263 ^(B)	(-)3.00	1.71300	53.83
66	-36.314	(-)16.00	1.65713	49.55
67	248.631	(-)110.10	AIR	
20				
68	74.719	(-)5.00	1.72825	28.41
69	105.464 ^(B)	5.00	1.72825	28.41
70	74.719	110.10	AIR	
25				
71	248.631	16.00	1.65713	49.55
72	-36.314	3.00	1.71300	53.83
73	-236.263	60.00	AIR	
74	-129.938	20.00	1.49176	57.45
75	-44.461 ^(A)	0.25	AIR	
30				
76	30.359 ^(A)	20.00	1.49176	57.45
77	-141.178			

^(A)Aspheric (conic) surfaces

Surface No 61 Asphericity -1.00229

35 Surface No 75 Asphericity -0.04036

-12-

Surface No 76 Asphericity -1.17224

^(B)Reflecting surfaces

This design provides a magnification of x4 with a horizontal field of view up to 18°, equivalent to 72° in the image. The eye relief for the dimensions given in the table is about 25 mm and the eye 'ring' has a horizontal dimension up to 15mm. The Z-fold angles are approximately 12°. Focusing may be obtained by movement of the central doublet.

10 Table 2 10X magnification version

Surface Number	Radius of Curvature (mm)	Axial Separation (mm)	Refractive Index	V-value (constringence)
81	105.820 ^(A)	9.72	1.49176	57.45
15 82	-219.202	105.00	AIR	
83	107.666	10.00	1.67269	32.21
84	-39.190	3.00	1.71300	53.83
85	-471.032 ^(B)	(-)3.00	1.71300	53.83
20 86	-39.190	(-)10.00	1.67269	32.21
87	107.666	(-)108.00	AIR	
88	73.975	(-)5.00	1.72824	28.41
89	99.256 ^(B)	5.00	1.72824	28.41
25 90	73.975	108.00	AIR	
91	107.666	10.00	1.67269	32.21
92	-39.190	3.00	1.71300	53.83
93	-471.032	3.00	1.51680	64.17
30 94	20.627	80.00	AIR	
95	56.398 ^(A)	16.00	1.49176	57.45
96	-117.855			

-13-

		0.25	AIR	
97	56.398 ^(A)	16.00	1.49176	57.45
98	-117.855	0.25	AIR	
99	37.638	12.00	1.49176	57.45
5	100	350.631		

^(A)Aspheric surfaces

	Surface No 81	Conic	-2.24327	A6	-2.022 x 10 ⁻¹¹
	Surface No 95	Conic	-6.24301		
10	Surface No 97	Conic	-6.24301		

^(B)Reflective surfaces

This design provides a magnification of x10 with a horizontal field of view up to 8°, equivalent to 80° in the image. The eye relief for the dimensions given is about 26mm. The Z-fold angles are approximately 14° and 7°.

Embodiments of the invention can provide a high quality viewing instrument with greater ease and comfort of use.

In this specification and the appended claims an erecting mirror is one of a pair of mirrors the second of which projects an image which is inverted with respect to the image received by the pair of mirrors. Normally each of said mirrors would have optical power effectively in the same manner as a concave mirror.

Whilst in the above description, the full available horizontal and vertical apertures and fields with be used, it would be possible to cut these down from the inherent apertures and fields available to give circular or other apertures and fields.

-14-

C L A I M S

1. An optical system for telescopes and binoculars having an optical path folded by erecting mirrors and compromising at least one lens characterised in that the system has an inherent aperture and field greater in a direction transverse to a direction in which the path is folded.

2. An optical system for telescopes and binoculars comprising an objective lens unit and an eyepiece lens means with an optical path therebetween folded by erecting mirrors characterised in that the system has an aperture and field greater in a direction transverse to a direction in which the path is folded.

3. An optical system according to claim 1 or claim 2 wherein the optical path is folded Z-like tightly on itself.

4. An optical system according to claim 3 wherein the angles contained in the Z are no greater than 30°.

5. An optical system according to any one of the preceding claims having a viewing axis wherein the said aperture and field are offset from said viewing axis.

6. An optical system according to claim 2 or any subsequent claim as dependent on claim 2 wherein one or more of said unit, said means and mirrors is aspherical not having a point centre of curvature but a zone containing the centres of curvature which can be regarded as a centre of curvature.

7. An optical system according to any one of the preceding claims wherein at least one of the mirrors has associated with it a lens so forming a Mangin mirror.

8. An optical system according to claim 2 or any subsequent claim as dependent on claim 2 wherein the unit and means have principal foci and the mirrors have centres of curvature which do not all fall on one common axis.

35

9. An optical system according to claim 8 wherein a first of the mirrors has its centre of curvature not more than one-tenth of its radius of curvature from a viewing axis.

5 10. An optical system according to claim 9 wherein said radius of curvature is between a half and twice the first mirror's spacing from said unit.

11. An optical system according to claim 2 or any subsequent claim as dependent on claim 2 wherein the said
10 unit has a focal length such that a primary image is formed on or near the first of the mirrors.

12. An optical system according to claim 11 wherein the second mirror projects an image adjacent the means.

13. An optical system according to claim 11 wherein
15 the means is a Huygens-type eyepiece.

14. A pair of binoculars comprising a pair of optical systems according to any one of the preceding claims arranged side-by-side with the larger field and aperture of each system in the same direction which in use
20 will be parallel to the eye separation of the user.

15. A pair of binoculars according to claim 14 wherein an exit pupil for at least one of the systems is in the form of an elongated slot extending in the direction of the larger field and aperture.

25 16. A pair of binoculars according to claim 15 wherein the pair of systems are at a fixed separation.

17. A pair of binoculars according to claim 16 which is arranged in a collapsible housing having two hinged housing parts mounting the unit mirrors and means
30 arranged so the housing can be pivoted together for carrying and allowed to open out for use.

18. A pair of binoculars according to claim 16 which is arranged in a housing which is arranged to telescope into a shorter length.

-16-

19. A pair of binoculars according to any one of claims 14 to 18 wherein each system is provided with periscope-type sighting means.

20. A pair of binoculars according to claim 19 wherein that sighting means is arranged with a pair of mirrors arranged to allow sighting and then viewing in a manner similar to a reflex camera.

21. A pair of binoculars according to any one of claims 14 to 20 having an eyepiece lens means wherein the power of all optical surfaces is low relative to normal binoculars and having brow rests spacing the wearer's eyes a relatively large distance from the eyepiece lens means so the wearer can use any spectacles he normally uses.

22. A pair of binoculars according to any one of claims 14 to 21 having means for displacing at least one of the optical elements to adjust for near or distant objects.

23. A pair of binoculars having an eyepiece lens means with relatively low surface powers so the user's eyes will be a relatively long distance behind said means enabling him to wear his normal spectacles.

25

30

1/7

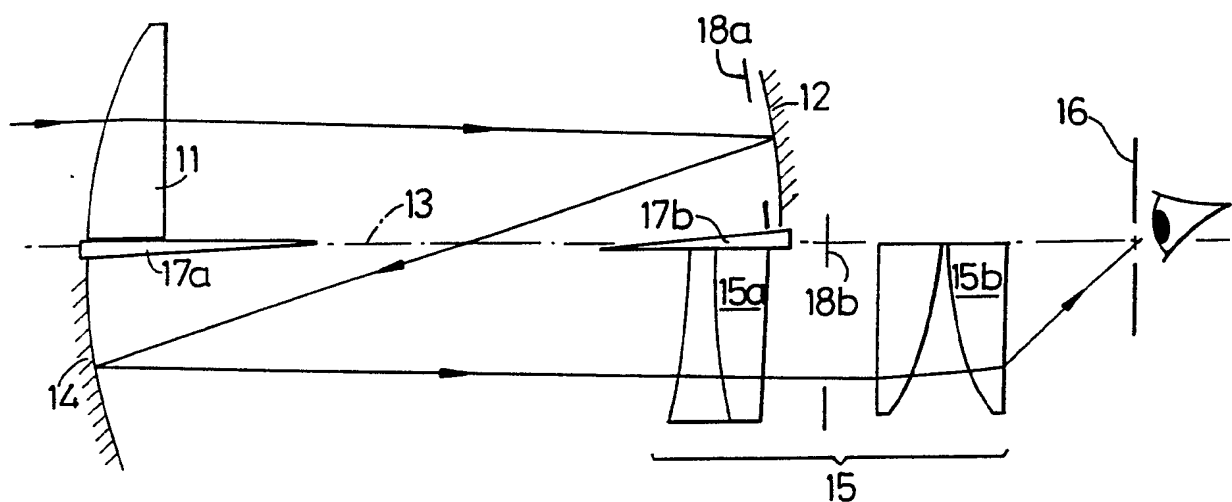


Fig. 1

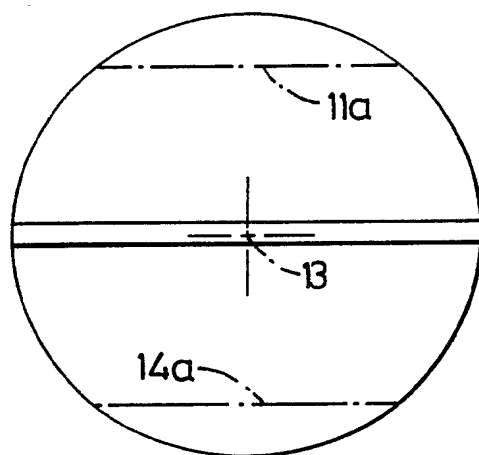


Fig. 1A

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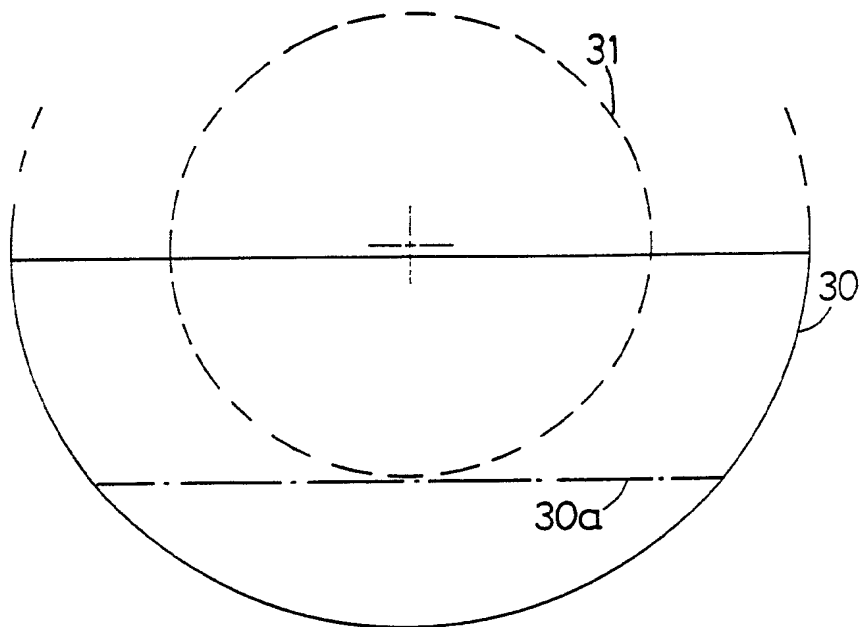


Fig. 2

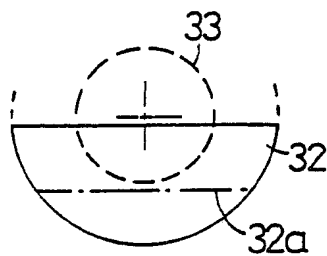


Fig. 3

4/7

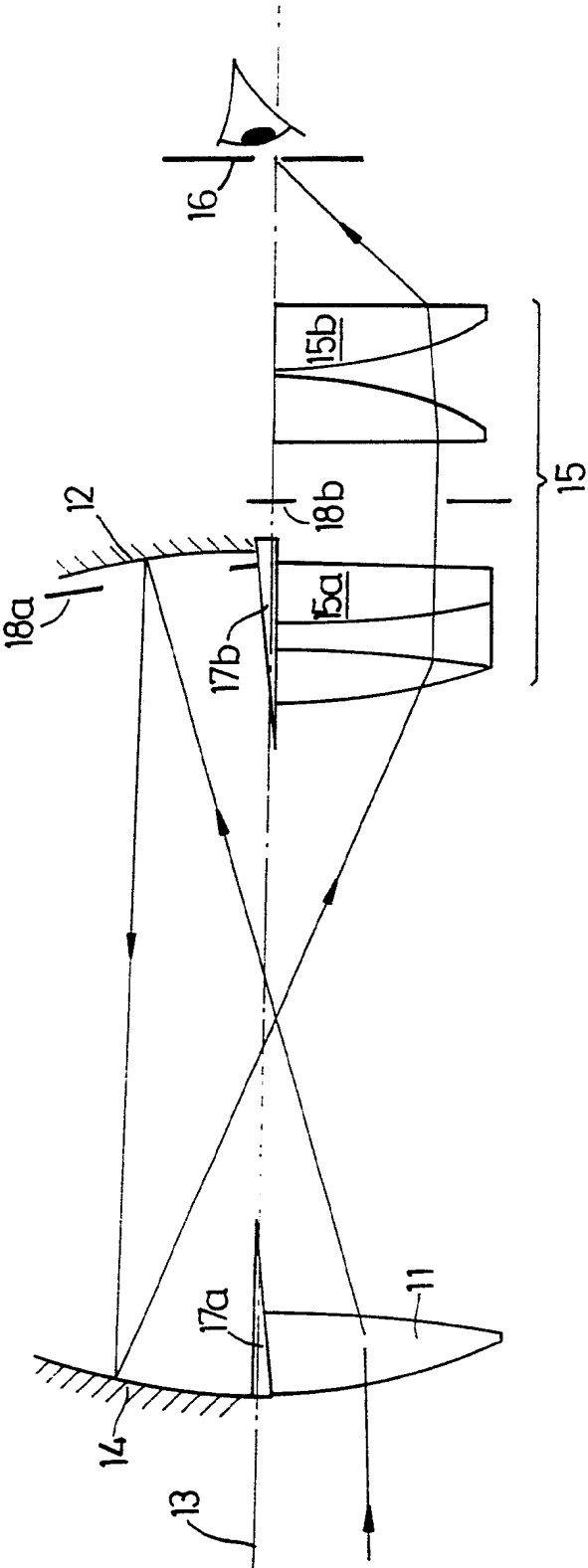


Fig. 5

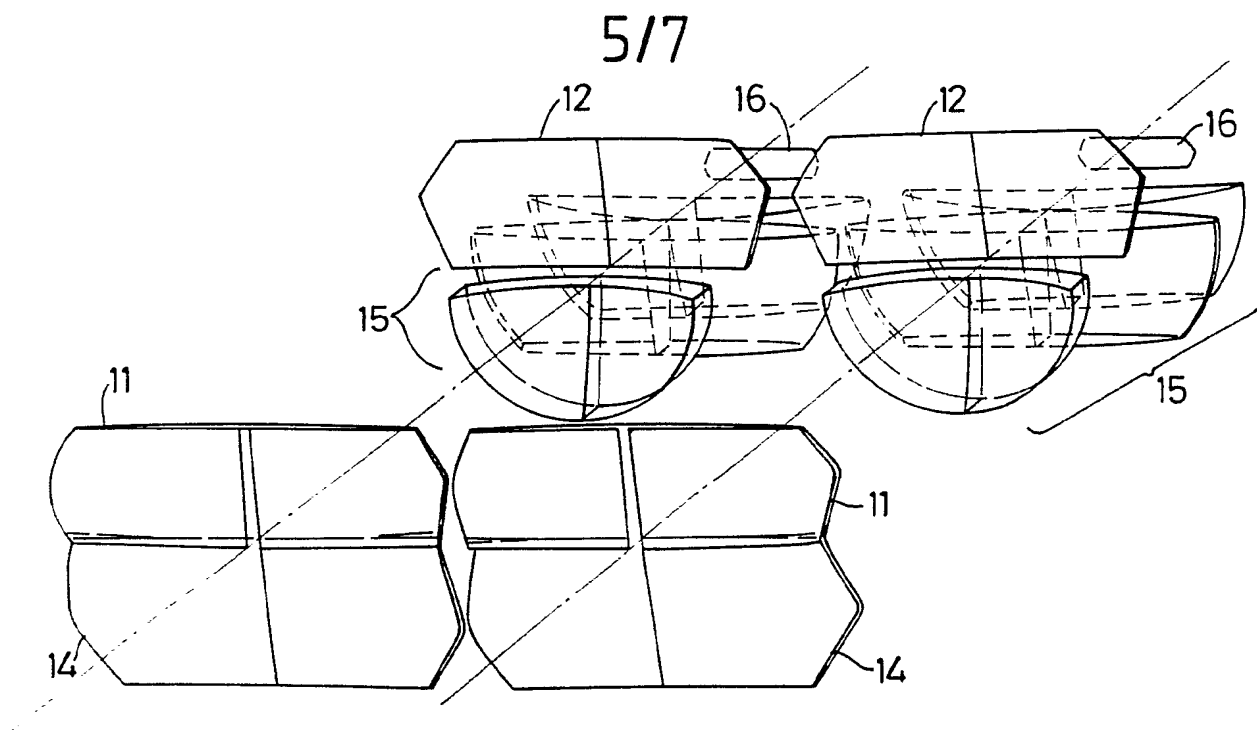


Fig. 6

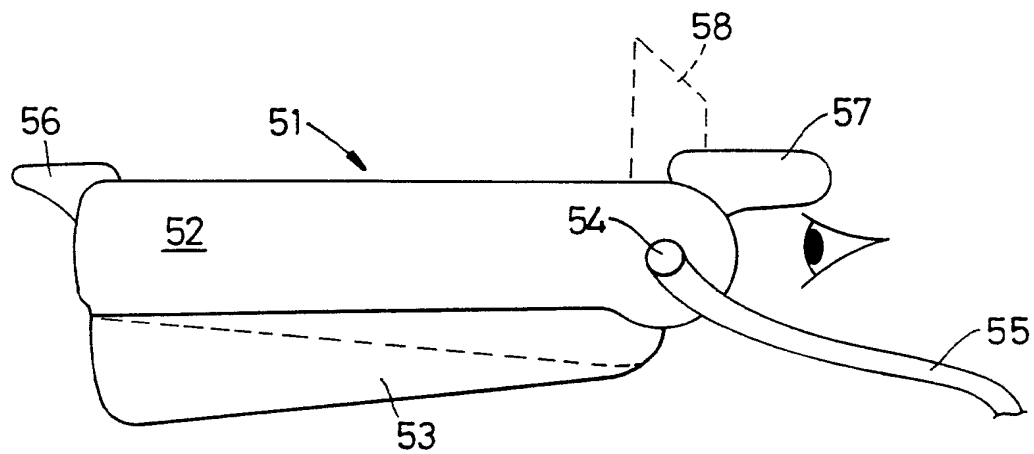


Fig. 7

617

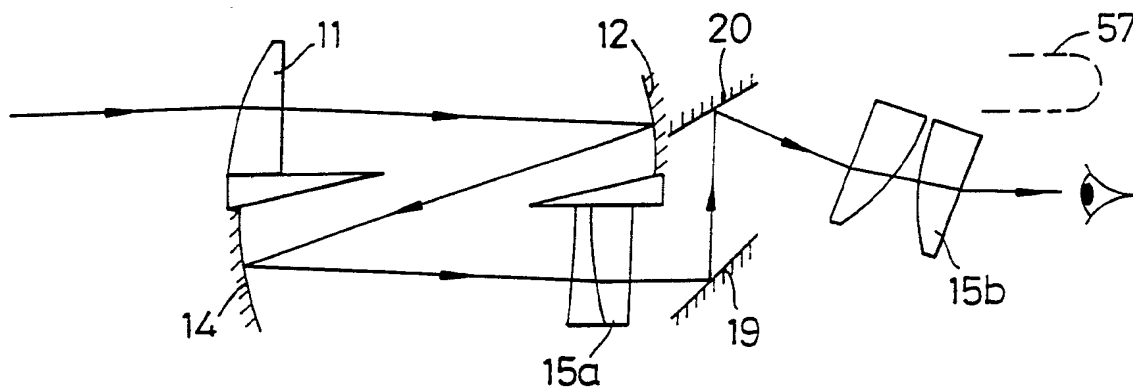


Fig. 8

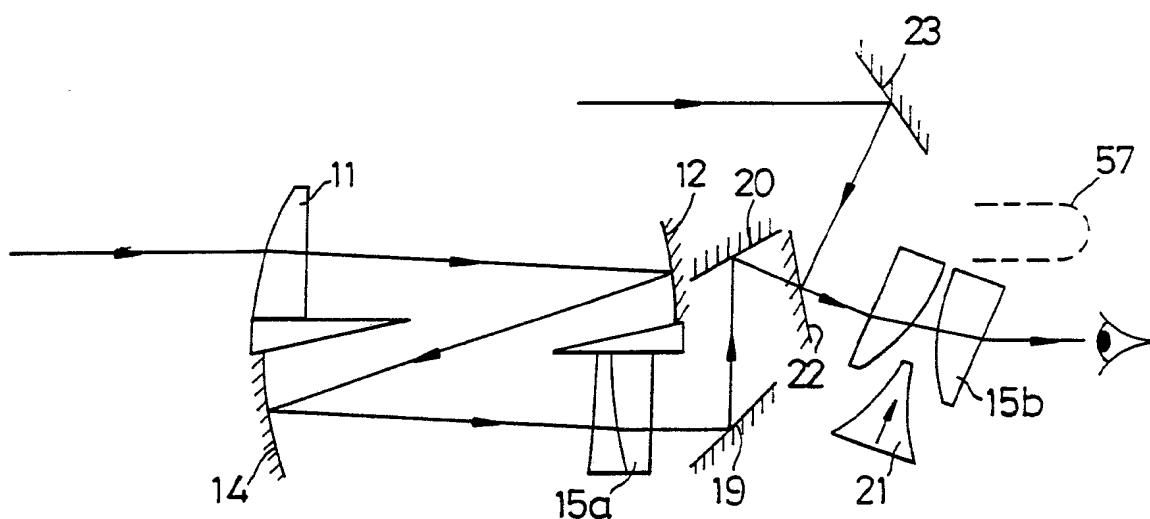


Fig. 9

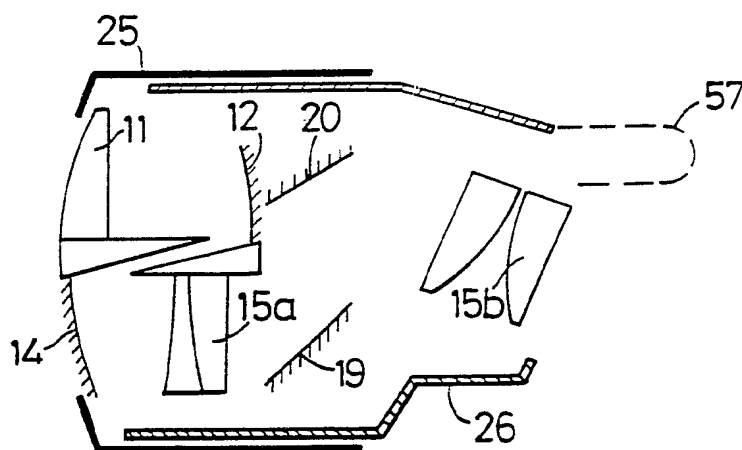


Fig. 10

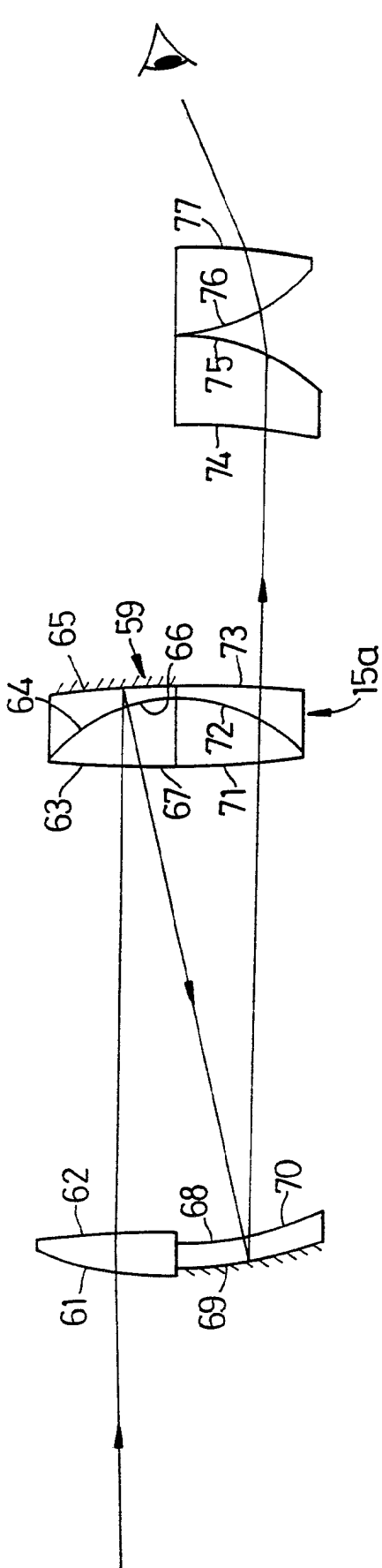


Fig. 11

7/7

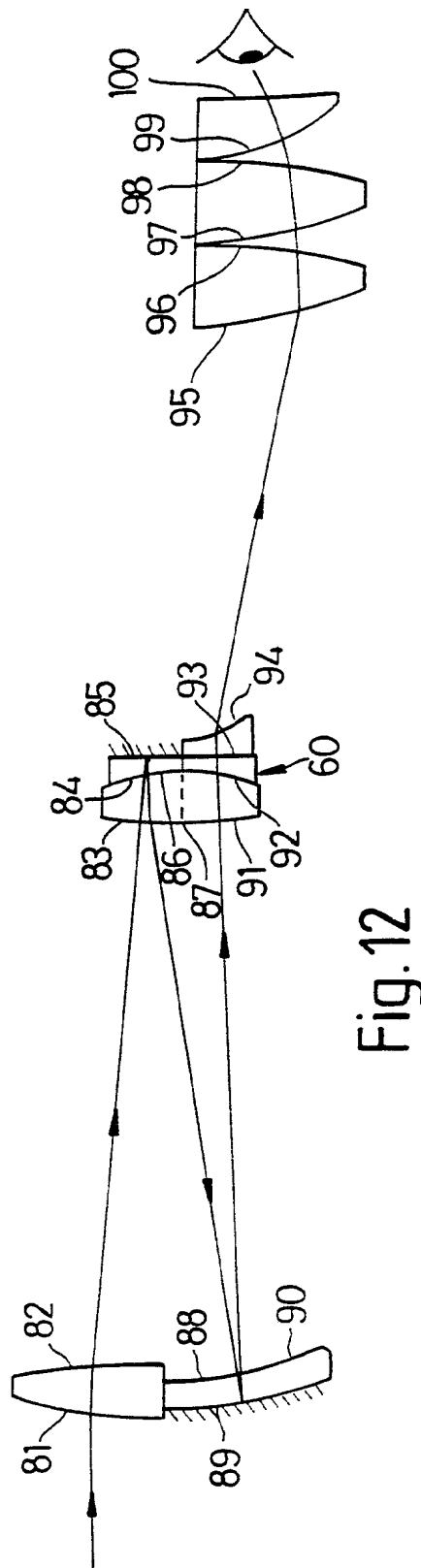


Fig. 12